TRIUMF

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SCIENTIFIC ACTIVITIES
1997

CANADA'S NATIONAL MESON FACILITY
OPERATED AS A JOINT VENTURE BY:

UNIVERSITY OF ALBERTA
SIMON FRASER UNIVERSITY
UNIVERSITY OF VICTORIA
UNIVERSITY OF BRITISH COLUMBIA

ASSOCIATE MEMBERS:

UNIVERSITY OF MANITOBA
UNIVERSITÉ DE MONTRÉAL
UNIVERSITY OF REGINA
UNIVERSITY OF TORONTO

UNDER A CONTRIBUTION FROM THE
NATIONAL RESEARCH COUNCIL OF CANADA

APRIL 1998

The contributions on individual experiments in this report are outlines intended to demonstrate the extent of scientific activity at TRIUMF during the past year. The outlines are not publications and often contain preliminary results not intended, or not yet ready, for publication. Material from these reports should not be reproduced or quoted without permission from the authors.

CYCLOTRON OPERATIONS DIVISION

INTRODUCTION

The goal in 1997-98 was to operate the cyclotron within a very low budget and with minimal manpower. Most of the personnel were either seconded to the ISAC project, or helping with the CERN collaboration. Collaboration on technology transfer with Grumman Corporation also required key manpower and one member of the division served as a liaison for the SNO project. In this framework the modest 87.7% cyclotron availability achieved should be seen as a success. This has resulted in part from careful preventive maintenance done in previous years, and in part from the steady competence and dedication of our cyclotron operators. The determination and efficiency of a few cyclotron engineers and technicians in keeping the priority on some of the most urgent maintenance activities was also an important factor. Remarkable was the excellent cyclotron polarized beam performance (93% availability) obtained while using the optically pumped polarized ion source, thanks to good work by our polarized source experts.

However, the achievement of only 70% of the scheduled beam current in beam line 1A is unsatisfactory and will require future attention. There were two main reasons. Firstly, a recurring vacuum leak between the target T2 and the secondary beam line M20 (in a region of high residual activation) resisted several attempts at repair by the Remote Handling group, until an intrinsic weakness in the original mechanical design was pointed out and acted upon. A very precise and special insert had to be installed to allow the vacuum and bellows system to function. During the last period of high current this insert worked fine and we hope it may have solved the problem. Otherwise an overhaul of the M20 secondary line, which may take a few months of beam line shutdown and several man-months of specialized beam line personnel, may be required. Secondly, the coupling loop to the AEC (or rf cyclotron booster), which reduces by $\sim$ 30% the electromagnetic stripping losses in the high energy extraction region, failed repeatedly. Here again the original design appears to be marginal and a redesign is necessary. Some resources both in budget and skilled manpower will be required for this. Beam line 2C operation was dedicated mainly to isotope production during high intensity operation, and mainly to eye melanoma cancer therapy during low or polarized beam current. The low energy beam ($\sim$70 MeV) operated satisfactorily with reduced personnel dose-exposure for maintenance.

To conclude, cyclotron operation is coping better than expected with the assignment of several resources to other site priorities. It may cope for another one or two years, while we are building ISAC; however, when again we require a reliable machine to produce the primary proton beam for ISAC and other high intensity activities, some resources and priority will have to be reassigned to the cyclotron and its ancillary systems to maintain our traditional good operational reliability and perform much needed system improvements.

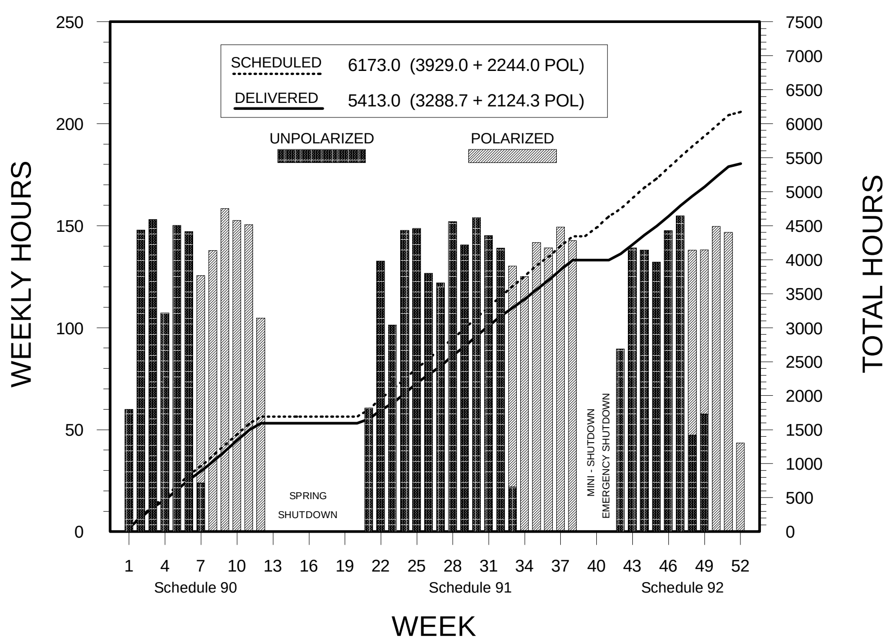


Fig. 96. Operational hours for 1997.

BEAM PRODUCTION

This report describes beam production for the full 1997 calendar year, starting with the completion of Schedule 90 and ending with the first eleven weeks of Schedule 92. A total of 6173 operational hours were scheduled of which 5413 were achieved for an availability of 87.7%. As shown in Fig. 96, these hours were split roughly 3:2 between high current beam production and low intensity, polarized operation with the availability considerably better for the latter. The totals include 177 hours used for development and tuning. While high intensity periods served a variety of users, polarized operation was for the most part dedicated to the parity non-conservation experiment running in beam line 4A2. The total beam charge delivered to meson hall experiments during high current production was 381 mAh or 70.3% of that scheduled (Fig. 97). This percentage is lower than the availability largely because of several weeks of reduced intensities throughout the year whenever the persistant air leak at 1AT2 resurfaced and also during a difficult startup to Schedule 92. (It should also be noted that this was the first year that 150 μA rather than 140 μA was the scheduled current – otherwise the availability would be 5% higher.) There were also 90.6 mAh delivered at 85 MeV to the solid target facility (STF) in beam line 2C4 for the production of radiopharmaceutical generators while 13 patients were treated for ocular melanomas during seven proton therapy sessions in beam line 2C1. The annual downtime (Fig. 98) was 776 hours, the third highest it has been in the last dozen years. As with the previous high-downtime years, rf problems accounted for the lion's share, this time about three quarters of the total and largely due to a water leak in the cyclotron.

Beam schedule 90

The operational record and beam to experiments for the year are given in Tables VIII and IX. The year started with the repair of the M20Q1-T2 indium seal after the cooldown over the Christmas break. The leak opened up again towards the end of the high current schedule after a T2 target ladder swap and required BL1A intensities to be reduced to around 60 μA. The rf booster had been running the previous year and it continued to help maintain a decent machine tune throughout this high current production period with the cyclotron transmission typically 58%. The STF lost a week of charge after a failure of its latching mechanism during a routine test irradiation. During polarized operation, the cyclotron was tuned to 13% transmission (with no bunchers) as 400 nA was circulated for parity which extracted 200 nA of 80% longitudinally polarized, 223 MeV beam. Their start-up was jeopardized by a transformer failure but power was successfully rerouted and parity went on to have a successful run. In addition to proton therapy runs, BL2C1 was used to extract lower energies into the proton irradiation facility (PIF) to complement the higher energies run via BL1B during the last week of Schedule 90. PIF went well but did have difficulty at 200 MeV with the beam too high in the machine so moved to 225 MeV where this was not a problem. During this period of low intensity operation, the Remote Handling crew set about repairing the M20Q1-T2 vacuum leak.

Spring shutdown

The spring shutdown started on March 22. A shields-in radiation survey showed the cyclotron to be about 20% cooler than it was the previous spring, partly due to the use of the rf booster during high current operation. The main thrust of the shutdown was to install the 2A extraction probe and the front end components of BL2A (a combination magnet, two quadrupoles, a rad-hard valve and services) and then test the line by extracting a few nanoamps of 485 and 500 MeV beam into a temporary carbon dump in the vault. This operation went very well. Other vault shutdown jobs included probe maintenance including an overhaul of extractor 2C, and BL2C shineblocker and STF repairs. BL1A shutdown work saw 1AT2 area vacuum leaks repaired and T2 water package modifications completed. The final dose statistics for the spring shutdown showed 110 workers receiving a total of 126.5 mSv.

Beam schedule 91

During high current operation the machine transmission was typically 58% with tank spills of 3 μA. Although the rf booster had run well during the previous beam schedule, it remained inoperable this time after two failures during or soon after the conditioning process. In both cases there was a tank vacuum burst when the RFB feedthrough ceramic cracked. The successful replacement of extractor 2C's shear plate has once again allowed currents greater than 50 μA to be delivered to 2C4. One landmark of this period was the simultaneous extraction of protons down four primary beam lines during a 2A tuning test in early June. A brief test in BL2C5 saw up to 15 μA run into the cesium target. A 7 μm diameter carbon stripping wire helped achieve the desired split ratio for experiment 704 in BL4B but did not improve beam quality as hoped. This experiment also had some difficulty extracting the desired beam at a couple of energies where the beam was too high in the cyclotron. Some rather uncharacteristic summer lightning strikes did more than toll up a little downtime. In one case the site phone system was disrupted for more than a week while other storms created havoc with the fire detection

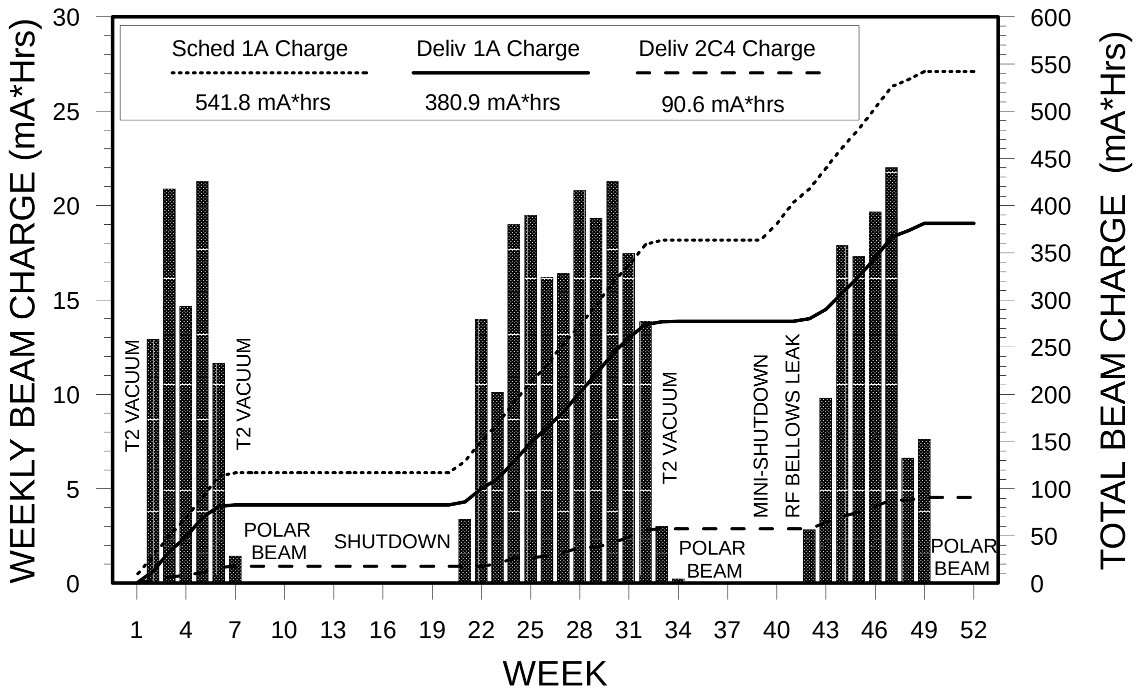


Fig. 97. Beam delivery for 1997.

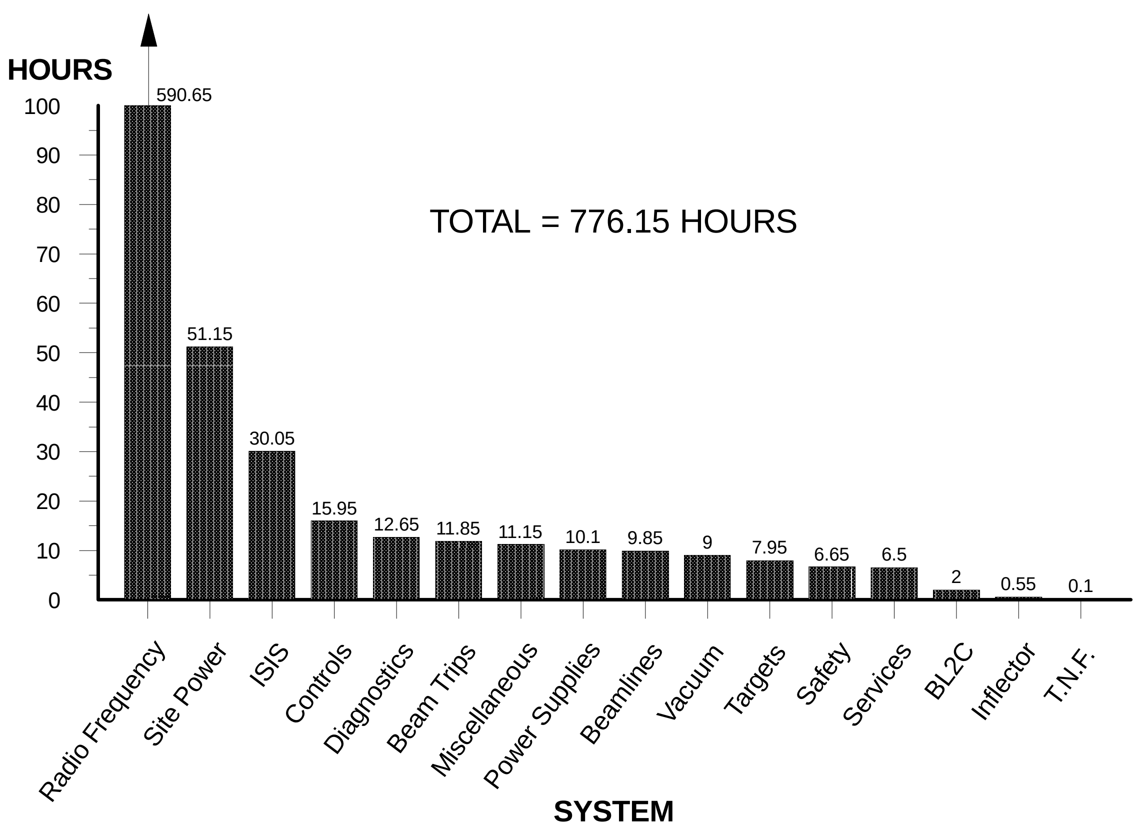


Fig. 98. Cyclotron downtime for 1997.

Table VIII. Operational record for 1997.

	Scheduled hours			Actual hours		
Cyclotron off:						
Maintenance	497.0			484.75		
Startup	347.0			287.65		
Shutdown	1646.5			1646.50		
Other	8.0			7.50		
Cyclotron downtime	0.0			776.15		
Overhead	64.5			120.50		
Totals	2563.0			3323.05		
Cyclotron on:						
Development	45.0	+	39.0 P	15.40	+	34.60 P
Cyclotron tuning	216.0	+	115.0 P	50.30	+	76.65 P
Beam to experiments	3668.0	+	2090.0 P	3222.95	+	2013.05 P
Totals	3929.0	+	2244.0 P	3288.65	+	2124.30 P
Beam to experiments:						
1A Production	3626.0	+	104.0 P	3001.60	+	94.80 P
1A Development/tuning	0.0	+	0.0 P	20.35	+	2.75 P
1A Downtime/open/no user	42.0	+	1783.5 P	201.00	+	1721.20 P
1B Production	0.0	+	122.0 P	0.00	+	30.50 P
1B Development/tuning	0.0	+	0.0 P	0.00	+	6.45 P
1B Downtime/open/no user	0.0	+	80.5 P	0.00	+	157.35 P
Total 1A+1B production	3626.0	+	226.0 P	3001.60	+	125.30 P
2C1 Production/tests/tuning	280.0	+	275.0 P	64.55	+	37.65 P
2C4 Production/tests/tuning	2560.0	+	0.0 P	1940.45	+	0.15 P
2C5 Development/tuning	12.0	+	0.0 P	20.05	+	0.00 P
4A2 Production	104.5	+	1733.5 P	120.40	+	1260.15 P
4A2 Development/tuning	0.0	+	0.0 P	1.05	+	122.70 P
4A2 Downtime/open/no user	150.0	+	50.0 P	105.05	+	318.90 P
4A3 Production	1707.5	+	202.5 P	1188.30	+	187.60 P
4A3 Development/tuning	0.0	+	0.0 P	11.70	+	0.55 P
4A3 Downtime/open/no user	13.5	+	0.0 P	343.85	+	22.95 P
4B Production	1667.0	+	100.0 P	1124.80	+	52.25 P
4B Development/tuning	0.0	+	0.0 P	28.60	+	9.90 P
4B Downtime/open/no user	25.5	+	4.0 P	317.20	+	38.05 P
Total BL4 production	3479.0	+	2038.0 P	2410.05	+	1500.00 P
1A Beam charge		541770 μAh			380921 μAh	
2C4 Beam charge		107970 μAh			90578 μAh	

(3288.65 + 2124.30) / (3929 + 2244) = 87.7 % Availability

P = Polarized source on-line (although not necessarily polarized beam)

Table IX. Beam to experiments for 1997.

			Scheduled			Delivered		
Experiment*	Channel	Sched.#	h	h (pol)	μAh	h	h (pol)	μAh
421	4A3	90	104.0	0	0	53.6	0	0
421	4A3	91	46.0	0	0	7.0	0	0
497 TEST	4A2	90	46.0	0	0	46.7	0	0
497	4A2	90	0.0	585	0	0.0	492.35	0
497	4A2	91	0.0	672	0	410.9	0	0
497	4A2	92	58.5	476.5	0	55.65	356.85	0
560	M11	92	924.5	0	138685	834.65	0	103683
581	M13	90	58	0	8120	57.35	0	6290
603	M13	90	213.0	0	29820	213.6	0	29699
614	M13	91	169.5	104	26465	156.6	94.8	16190
640	M13	90	196.0	0	29410	95.95	0	12033
648	M15	91	127.0	0	19050	91.65	0	8596
657	M9B	90	369.0	0	54660	277.6	0	40387
658	M13	90	104.0	0	14560	5.6	0	60
658	M13	91	150.0	0	22500	121.35	0	14290
658	M15	90	150.0	0	21000	150.15	0	19198
658	M20B	91	219.0	0	32850	65.65	0	7675
669	M15	91	104.0	0	15600	94.15	0	8750
684	M9B	91	392.0	0	58800	376.45	0	51516
684	M9B	92	427.0	0	64050	411.3	0	56808
687	M13	92	150.0	0	22500	143.45	0	19933
687	M15	91	150.0	0	22500	145.85	0	19872
687	M15	92	104.0	0	15600	96.8	0	13233
691	M15	90	127.0	0	19050	102.6	0	6379
691	M15	91	146.5	0	21975	145.1	0	19410
700	4B	91	83.0	21	0	0	52.25	0
703	M13	91	150.0	0	22500	140.45	0	19234
704	4B	90	125.5	0	0	95.45	0	0
704	4B	91	872.5	0	0	711.5	0	0
704	4B	92	508.0	0	0	317.85	0	0
706	M15	92	188.5	0	26390	186.35	0	14475
713	M9B	91	231.0	0	34650	223.7	0	31343
713	M9B	92	196.5	0	29475	200.7	0	28367
714	4A3	90	0.0	112.5	0	0	98.05	0
715	4A3	90	321.5	0	0	249.75	0	0
715	4A3	92	358.0	0	0	284.8	0	0
719	M11	90	675.0	0	97500	554.15	0	76436
724	M15	90	104.0	0	14560	5.6	0	60
724	M15	91	115.0	0	17250	118.5	0	16114
728	4A3	90	0.0	90.0	0	0	89.95	0
735	M13	91	150.0	0	22500	151.0	0	21310
735	M20B	91	254.0	0	38100	243	0	33930
737	M20B	91	150.0	0	22500	151	0	21310
737	M15	92	150.0	0	22500	147.2	0	20317
741	4A3	91	473.0	0	0	454.2	0	0
742	M20B	90	427.0	0	64050	380.2	0	46766
744	M9B	90	127.0	0	19050	102.6	0	6379
744	M9A	91	127.0	0	19050	91.65	0	8596
746	M15	90	81.0	0	12150	69.7	0	9867
746	M20B	90	104.0	0	14560	5.6	0	60
746	M20B	92	151.0	0	22650	122.4	0	11700

Table IX (cont'd.)

Experiment*	Channel	Sched.#	Scheduled h	Scheduled h (pol)	Scheduled μAh	Delivered h	Delivered h (pol)	Delivered μAh
749	M15	90	121.0	0	16940	120.8	0	16791
749	M20B	91	150.0	0	22500	143.05	0	19738
749	M20B	92	150.0	0	22500	143.45	0	19933
751	M20B	90	150.0	0	27440	150.15	0	19198
751	M20B	91	146.5	0	21975	145.1	0	19409
752	M20B	90	121.0	0	16940	120.8	0	16791
757	M9B	90	121.0	0	16940	120.8	0	16791
757	M20B	91	127.0	0	19050	130.9	0	18199
758	M20B	91	115.0	0	17250	118.5	0	16114
758	M20B	92	95.0	0	14250	54.2	0	2826
768	M15	90	150.0	0	22500	146.75	0	21716
774	M15	90	69.0	0	10350	61.15	0	8804
774	M20B	91	150.0	0	22500	121.35	0	14290
774	M20B	92	124.0	0	18600	119.1	0	14302
775	M13	91	265.0	0	39750	261.55	0	35762
775	M13	92	138.0	0	20700	91.6	0	5586
776	M15	91	150.0	0	22500	140.45	0	19234
777	M15	91	150.0	0	22500	151	0	21310
777	M15	92	81.5	0	12225	79.5	0	10919
781	M11	91	273.5	21	42065	261	20.95	31375
782	M20B	91	150.0	0	22500	140.45	0	19234
782	M20B	92	150.0	0	22500	153.7	0	21995
783	M15	91	127.0	0	19050	112.1	0	15730
784	M13	91	115.0	0	17250	65.65	0	7675
785	M11	91	1361.0	0	204150	1239.9	0	161968
786	4A3	91	127.0	0	0	106.95	0	0
789	M20B	91	150.0	0	22500	145.85	0	19672
789	M13	92	127.0	0	19050	120.65	0	16558
790	M15	91	300.0	0	45000	264.4	0	33938
791	M15	91	115.0	0	17250	65.65	0	7675
791	M15	92	150.0	0	22500	153.7	0	21995
792	M20B	91	127.0	0	19050	91.65	0	8596
793	4A3	91	81.0	0	0	57.45	0	0
794	M9B	91	127.0	0	19050	115.9	0	11079
794	M9B	92	151.0	0	22650	122.4	0	11700
795	M9B	90	185.0	0	25900	155.75	0	19258
797	M15	92	151.0	0	22650	122.4	0	11700
804	M20B	92	127.0	0	19050	120.65	0	16558
809	M13	92	151.0	0	22650	122.4	0	11700
814	M15	92	150.0	0	22500	143.45	0	19933
819	M9B	91	146.5	0	21975	145.1	0	19410
819	M9B	92	138.0	0	20700	91.6	0	5586
822	M15	92	138.0	0	20700	91.6	0	5586
BELLE	M15	91	0.0	104	1040	0	94.8	886
CHAOS	M13	92	92.0	0	13800	93.15	0	13268
DEV	2C5	91	12.0	0	0	14.25	0	76
FINUDA	M11	90	127.0	0	19050	102.6	0	6379
FOILS	2C4	92	0.0	0	0	3.1	0	23
ISOPROD	2C4	90	566.0	0	25400	369.15	0	18066
ISOPROD	2C4	91	1023.5	0	43795	1002.75	0	39421
ISOPROD	2C4	92	717.5	0	35875	660.5	0	32978

Table IX (cont'd.)

Experiment*	Channel	Sched.#	Scheduled h	Scheduled h (pol)	Scheduled μAh	Delivered h	Delivered h (pol)	Delivered μAh
KOVASH	M13	92	81.0	0	12150	82.9	0	11928
KLAUSS	M13	90	231.0	0	34650	207.7	0	30170
KLAUSS	M13	91	277.0	0	41550	257.95	0	35602
LI	M9A	91	115.0	0	17250	94.35	0	10255
PIF	1B	90	0.0	67	0	0	11.65	0
PIF	1B	92	0.0	55	0	0	18.85	0
PIF	2C1	90	0.0	23	0	0	9.65	0
PIF	2C1	92	46.0	0	0	25.6	13.15	0
P THERAPY	2C1	90	115.0	122	0	7.8	3.8	0
P THERAPY	2C1	91	58.0	100	0	16.35	4.6	0
P THERAPY	2C1	92	51.0	11	0	8.05	4.05	0
PT TEST	2C1	90	0.0	168	0	4.0	1.15	0
SI	M13	91	185.0	0	27750	188.85	0	26424
TBA	4A2	90	66.0	0	0	0	0	0
TBA	4A3	90	58.0	0	0	0	0	0
TBA	M9B	91	69.0	0	10350	67.75	0	9201
TBA	M13	91	46.0	0	6900	46.55	0	6080
TBA	M13	92	23.0	0	3450	23.95	0	3416
TEST	2C5	92	0.0	0	0	4.3	0	34
TEST	M9B	91	300.0	104	45000	264.4	0	33938
TEST	M15	91	127.0	0	19050	130.9	0	18199
TEST	M20B	92	15.5	0	2325	15	0	2212
uSeRs	M13	91	127.0	0	19050	91.65	0	8596
uSeRs	M20B	92	69.0	0	10350	65.5	0	8775
YEN	M13	92	104.0	0	15600	100.9	0	13700

*See Appendix D for experiment title and spokesman

system. The final few weeks of high intensity operation were again threatened by a marginal 1AT2 area vacuum with BL1A currents reduced to less than 100 μA in the last days as the M20Q1-T2 indium seal air leak worsened. There was a small water leak at T1 requiring a target ladder change there; otherwise BL1A target performance was good. The polarized portion of the schedule saw a relatively disastrous parity run mainly due to inadequate target cooling but also because of problems arising with their intensity profile monitors (IPMs) and vault solenoid 2. Whenever these were not presenting a problem it seemed that there were tuning difficulties resulting from the poorer stability of the rf frequency during the summer. The one bright spot was the preliminary finding that the thin "hockey-stick" extraction foil seemed to have solved an offset problem with the plus/minus helicity data.

September mini-shutdown

Week 39 was scheduled as a "mini-shutdown" for extended maintenance prior to the resumption of high current production. It also provided the opportunity to install the section of BL2A beam pipe extending through the north vault wall. A day after the cyclotron lid was cycled to align a sagging resonator (4U3), a spontaneous water leak from a bellows on the water coolant circuit for resonator 2L1 brought about an emergency shutdown situation forcing a two-week delay to the high intensity schedule. The timing was fortunate in that cyclotron residual fields had dropped over the previous polarized schedule to levels comparable to those in the spring shutdown. Unfortunately the resonator in question first required the removal of many devices before it could be lifted for repairs and there were additional problems getting a tight seal when it was reinstalled. There was also a great amount of difficulty raising the cyclotron lid for the above jobs.

Nearly 35 mSv total dose was accrued in repairing the leak while another 5 mSv were obtained for other shutdown jobs, notably the completion of the latest repair of the M20Q1-T2 air leak.

Beam schedule 92

The first two weeks of high current production were marred by unusual start-up difficulties. A failed water pump saw BL4 power supply cooling (and therefore operation) sacrificed for 10 days to maintain enough flow from the remaining system pump to service other devices required for cyclotron and BL1A operation. BL1A tuning problems resulted from a shorted first quadrupole, a misaligned target protect monitor and then a slightly rotated 1AT1 target. Currents were significantly reduced during the diagnosis of these problems. The remaining 5 weeks of high current were fairly productive with a cyclotron transmission generally above 60% as 140 μA was delivered to BL1A at 500 MeV and 50 μA to BL2C4 at 85 MeV. After high current production had finished and BL1B had come on line for experiments in the proton irradiation facility, parity was struggling with target modifications and sparking transverse ion chambers (TRICs). With the CHAOS experiment in M11 in need of more beam and parity unsure of their readiness, a decision was made to switch back to high currents for a few days. Afterwards, the polarized source was brought back on line and parity was in excellent shape to begin taking data. Their target had cooled down in record time and the TRICs had stopped sparking after extended conditioning. Because the HE2 probe had failed a couple of weeks earlier, extraction 1 was used to horizontally shadow the special parity foil resulting in a few hundred nanoamps being run down BL1A at 220 MeV. It is notable that the latest M20Q1-T2 air leak repair has held up well during high current operation for the first time in a couple of years. Beam to parity halted just before Christmas as the cyclotron was turned off for the year end holidays.

BEAM AND CYCLOTRON DEVELOPMENT

The parity experiment is concerned about differences in beam position as small as 1 μm at the point of extraction if they are correlated with the direction of proton spin. The equations in GOBLIN that track spin motion had not included forces arising from the dot product of nuclear magnetic moment and gradients in the magnetic field; the Stern-Gerlach effect. The nuclear magneton is small but the Parity group were worried about effects that might accumulate over the 600–700 turns made to their extraction energy of 221 MeV. An analytic calculation, based on the smooth approximation, showed that one might anticipate a difference in radius at the point of extraction of $\sim 10^{-13}$ mm between particles injected with spin up and those injected with spin down. The frequency of vertical betatron oscillations will be slightly different for the two cases but the accumulated phase difference was calculated to be $\sim 10^{-13}$ radian. The magnetic moment terms were incorporated into the equations of motion in GOBLIN and a numerical calculation gave a radial difference of $\sim 2\times 10^{-11}$ mm. Calculations at this level are very subject to numerical noise. In any event both types of calculation predict differences well below the level of concern of the parity experiment.

RADIO FREQUENCY SYSTEMS

RF operations

The total cyclotron rf downtime for the year was 590 hours which represents 76% of the total machine down time. The major contribution was 312 hours for the repair of a failed resonator bellow, which we know is an ongoing problem that can happen at any time. This includes approximately 40 hours delay caused by the elevating system problems and another 40 hours due to start up problems. The combination of sparking, crowbars and out of drivens caused 111 hours of downtime, despite the fact that we adjusted a sagging resonator hot arm tip and cleaned a lot of sparking damage around the centre region area and in the beam gap. The rf booster coupling loop failed suddenly after 2 years of reliable operation causing 60 hours of machine down time. A new design has been fabricated and installed in the tank ready for testing in the new year. The combiners caused 46 hours of downtime this year. New combiners have been designed, assembled and tested at signal level, ready for installation when manpower becomes available. The remaining downtime caused by problems in the IPA, PA and HV power supplies was mostly due to aging components.

RF support

The remaining manpower load of the RF group was dedicated to the assembly of the RFQ components in preparation for the 7 ring RFQ tests and the CERN collaboration. On the RFQ, an important milestone was reached with a signal level frequency measurement of 36.1 MHz. The addition of the remaining 12 rings and the global tuners will bring the frequency down very close to the nominal frequency of 35 MHz. On the collaboration work for CERN, the design, fabrication and signal level testing on the copper clad wooden model of the 80 MHz HOM dampers, tuners and filters at TRIUMF, and the subsequent installation and power testing at CERN were very successful. The detail work on these projects is reported elsewhere.

RADIO FREQUENCY CONTROLS

The RF Controls group has been concentrating its effort on the ISAC project. The feedback control system for the ISAC pre-buncher is in the final construction phase. The system regulates an 11 MHz signal and up to its fourth harmonics in both amplitude and phase to synthesize a special waveform for beam bunching. Instead of amplitude and phase regulation, each harmonic is regulated by its in-phase and quadrature phase components using a single DSP. These harmonics are combined together and the resultant signal is used to drive a 1 kW wide band rf amplifier. Remote controlled operation of the control system is via Ethernet connection using UDP/IP to query status information and TCP/IP for command requests.

The cyclotron rf control system has been delivering very reliable performance. The frequency source has been upgraded to provide additional frequency stability. A long and short term frequency drift of less than 10 ppb is achieved.

In collaboration with CERN, the RF Control group is at present building modules in conjunction with the Diagnostics group for CERN beam diagnostics. These modules require minimal insertion loss, large amounts of phase shift but a high degree of phase stability, as well as high isolation between different signals. These objectives were achieved in our prototype designs.

DIAGNOSTICS

Probes and diagnostics mechanical MRO

A substantial effort was given in the first quarter to the installation and commissioning of the extraction probe for beam line 2A to ISAC which was completed during the spring shutdown. The priorities then shifted to the design and manufacture of the scanning-wire and multi-wire ion chamber profile monitors for beam line 2A. With the exception of some limited assistance for the parity experiment, all other non-ISAC related work was limited to essential repairs of the cyclotron probes and monitors.

The Diagnostics group biweekly meeting notes are available electronically via the Operations CYCINFO information service on the site computer cluster (accessible also through the TRIUMF home page on the WWW). The spring and fall shutdown activities are summarized in detail in the Diagnostics group meeting notes of May 23, 1997 and October 10, 1997. The notes relating to the 2A extraction probe and diagnostics are available in the same way via the ISACINFO information service.

Probes MRO

Extraction probe Ex2C was removed in the spring shutdown to install a new molybdenum shear plate and to replenish the extraction foil pack. With the new shear plate, the 2C beam current limitation could be lifted to beam intensities up to 80 μA. The water-cooled probe insert bellows began leaking in the summer, and the probe was disabled until the fall shutdown when the spare probe was installed. Unfortunately the IN limit failed to actuate when operated, so the probe will have to be serviced again in the spring 1998 shutdown. As experiments such as parity require high quality beam set-ups, extensive use is made of the cyclotron low and high energy probes. However, these aging devices are becoming less capable of running smoothly, resulting in limited capability to perform sensitive centering and shadowing procedures. The HE2 probe became stuck and was not operable at year end for the parity run. An extensive overhaul, or preferably, a replacement program will be required. Also, extraction probe Ex4 has a twisted structural aluminum extrusion which has been resulting in wear contributing to increased maintenance requirements. The group plans to replace this member in the fall shutdown of 1998 provided that a straight extrusion can be procured. Radiation damage to instrumentation cabling is becoming more common, and sections of cables are being replaced every shutdown, as damage becomes evident. Cabling closest to the beam plane was the first to be affected, but the problem will eventually affect much of the cabling in the vault and primary beam tunnels.

Monitors MRO

All vault beam line monitors were serviced during the spring and fall shutdowns. Monitor 1AM9 was replaced, and new cable extensions were installed. The monitors that use ferro-fluidic seals are developing leaks with increasing frequency. Monitors 4BM3, 4AM4, 4BM4 and 1VM4.6 all developed leaks. The temporary solution for these was to add fluid at the shaft–seal interface, but this remedy has a limited lifetime. As with the cyclotron probes, the MWIC monitor foil packs are reaching a service lifetime, as repeated maintenance begins to accumulate wear on threaded assemblies. In this case, the new MWIC design developed for beam line 2A will be an ideal replacement. This assembly utilizes multi-layer PC board technology to minimize the number of plates and seals. If sufficient resources become available, a much needed probes and beam line monitor overhaul and reconstruction program could begin in 1998-99 fiscal year.

VACUUM AND ENGINEERING PHYSICS

The cyclotron and beam lines vacuum systems operated well during the year with minimal downtime. An exception was the seal between M20 and T2 which failed four times between January and August. The investigation by the Remote Handling group led to a modified seal carrier which appears to have solved the problem.

Much time was spent on calculations and layout of ISAC vacuum systems. A large order for rotary vane and turbomolecular pumps was placed and received. The vacuum vessels for the RFQ and the target stations were fabricated and leak tested at the respective manufacturers' works. The RFQ vessel had two incomplete welds and one cracked weld. All were successfully repaired on the first attempt. The target vessels had numerous cracks in welds and required several attempts before repairs were successful. The final weld fillets were larger than specified, requiring modification of the shield plugs to provide clearance. Interlock logic for several sections of the LEBT and for the RFQ vacuum systems has been specified. The LEBT portion has been implemented by the Controls group and functions as expected. The vacuum connection from the cyclotron to the front end of beam line 2A was installed, including the rad hard valve.

Engineering Physics provided support to the RFQ and DTL efforts. Models of the DTL stem and ring assemblies were constructed and electrical and thermo/mechanical measurements were made. A "bead pull" device was constructed for use in the RFQ test tank, and general technical support was provided for the prototype tests. Major assistance was provided to the RF group in the preparation of the main RFQ tank and the general assembly and installaton of components.

ISIS AND POLISIS

H^- high intensity

The CUSP ion source and injection line continued to operate well for the past year. There were no major activities undertaken during the past year; minimal routine MRO was accomplished with reduced resources. ISIS personnel were involved, for the most part, designing and building the ISAC low energy beam transport systems (LEBT) and the off-line ion source (OLIS) with associated ancillaries, designing the ISAC building power distribution system, and commissioning the 1.76 MeV proton accelerator for the contraband detection system (CDS).

H^- polarized

The optically pumped polarized source (OPPIS) I4 provided reliable polarized beam to the parity experiment during 3 runs in 1997. Total beam delivery (including non-parity users) was 95% of the scheduled 2244 hours, and I4 was responsible for only 13 hours of downtime.

The split-plate detector used for measuring meV-scale energy modulation was replaced by an intensity profile monitor consisting of a 31-channel Ni foil harp, very similar to IPM3 in the parity experimental apparatus. The magnetic bender in the source spectrometer was replaced by an electrostatic deflector. These improvements now permit the helicity-correlated intrinsic beam position modulation and energy modulation to be measured independently of each other. Typical results for a well tuned source and laser system are energy modulation of a few meV and position modulation of ∼20 nm. (Please note that in the 1996 Annual Report, the editors erroneously changed meV to MeV in the POLISIS section). Figure 99 shows typical results while tuning up first one and then two lasers.

Typical helicity-correlated intensity modulation at the parity apparatus is a few times 10^{-5}. A chopped Ar laser beam copropagating down the 300 keV injection beam line can be used to modulate deliberately the H^- beam intensity via photodetachment. This allows the response of the parity detectors to pure intensity modulation to be calibrated and a correction to the data to be applied. The laser beam alignment system was

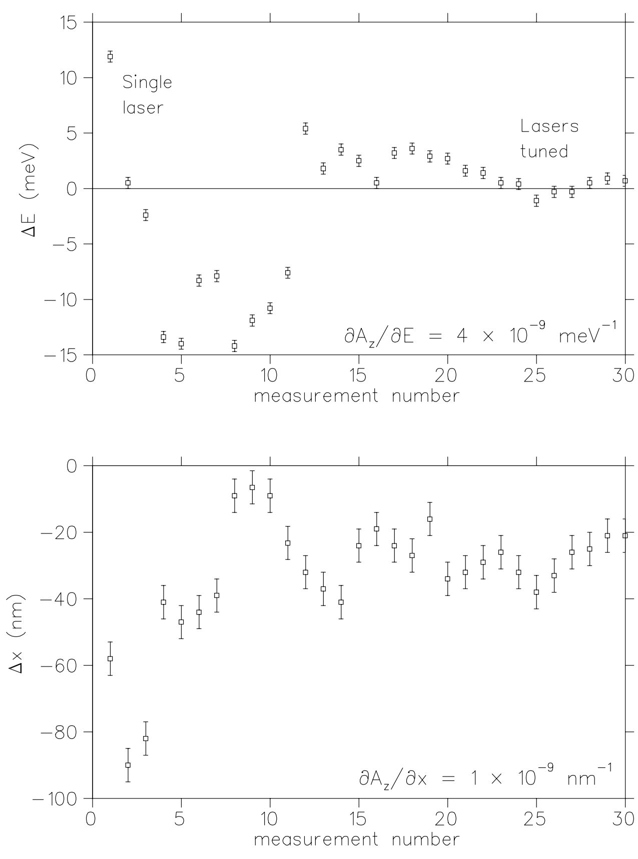


Fig. 99. Helicity-correlated energy and position modulation of the OPPIS beam, measured at the source Ni-foil spectrometer, as first one and then two lasers are used to optically pump the Rb vapour. The calibrated false contributions to the parity-violating analyzing power A_z measured at the parity apparatus, generated by helicity-correlated modulations, are indicated at the lower right of each graph.

improved, allowing ±0.2% intensity modulation to be consistently achieved.

Members of the group are designing the polarized ^{8}Li beam line, which will provide beams of polarized ^{8}Li ions to beta-NMR experimental stations in the ISAC LEBT area. The polarization will be induced by colinear optical pumping of neutral ^{8}Li atoms in a ∼1 m long polarizer. The neutral atoms will be produced by passing $^8Li^+$ ions at ∼12 keV through a sodium vapour neutralizer. The polarized ^{8}Li beam will then be reionized in a second cell to either Li^+ or Li^- and deflected and transported to the experimental station. Reionization of the beam is new and will allow varying the energy of the beam at the experimental target over a very large range, and permits running two or more targets simultaneously. It also keeps the targets isolated from sodium vapour and laser light. Tests to measure the yield and emittance growth of ion beams in various media will need to be carried out before the beam line design can be finalized. Colinear optical pumping can polarize species other than lithium (e.g. other alkali-metals, alkaline-earth ions, rare gases, oxygen) and high resolution optical spectroscopy of radioactive atoms will also be possible.

TRIUMF's leadership in high current polarized source development was recognized in tangible terms by KEK, BNL and DESY. The KEK OPPIS was shipped to TRIUMF in September to be recommissioned and upgraded to high current operation matching TRIUMF OPPIS standards. The goal is dc H^- current of 1.5 mA within a normalized emittance of 2 π mm mrad, with pulsed polarization of ∼80% provided by 100 μs laser pulses at up to a 10 Hz repetition rate. Upon completion, the KEK OPPIS will then be loaned to BNL for use at RHIC. DESY is also interested in high current OPPIS development, for possible use at HERA. The aim in their case is to show the feasibility of a pulsed source having a peak current of at least 10 mA within 2 π mm mrad with ∼80% polarization, using an INR, Moscow design that incorporates a very high current (3–5 A), high brightness proton source developed at BINP Novosibirsk. Unpolarized currents of 30 mA were demonstrated on a test stand that simulated the geometry of a working OPPIS.

PRIMARY BEAM LINES

Beam line 1A received an improved T2 water package system. The hydrogen recombiner system was replaced with a monitored expansion tank on the meson hall mezzanine to maintain high water resistivity and eliminate the possibility of uncontrolled release of active air. This was successfully tested in May and has operated without problems for the balance of the year.

A new target control system commissioning was completed in the early part of the year. The beryllium targets available at both T1 and T2 have operated well. Each target ladder now has a minimum of two beryllium targets available; the T1 ladders have two additional graphite targets. These graphite targets now have a consistent lifetime of two to three weeks using the new materials described in last year's Annual Report.

Other work on BL1A included the repair of the M13 beam blocker/gate valve, a water leak caused by a ceramic insulator failure at 1AQ10, a 1VQ1 quadrupole power cable short, and an M20 vacuum leak. This vacuum leak occurred at the mating flanges of the T2 vacuum chamber and the M20 beam line bellows. Over the past year this coupling has been a troublesome problem. Details of the mechanical problem and its present solution are given below in the report from the Remote Handling group.

The design and construction of beam line 2A is described elsewhere in this report. From an operational aspect, beam was extracted over an energy range from 472 MeV to 510 MeV without the combination magnet in place. This was done to commission the operation of the stripping mechanism and to verify the calculations of the exit locations of the extracted beams. During commissioning, simultaneous extraction of beam into beam lines 2A and 1A was also achieved.

The combination magnet and the first two vault quadrupoles were installed in the second quarter of the year. Installation of tunnel components began in the fall as they arrived and after being field mapped. All elements are expected to be installed by the end of April, 1998, at which time beam commissioning of the whole beam line will begin.

2C

During 1997, proton therapy on 2C1 was regularly scheduled for five days each month during high current and polarized beam operation.

In 1996, the production of the radioisotope ^{82}Sr that is produced in the solid target facility (STF) increased significantly because of demands by the customers of Nordion. This higher level of production continued in 1997. Irradiations for ^{82}Sr were 88.9 mAh in 123 days in 1997 compared with 92.3 mAh in 121 days in 1996. The isotope yields were 31.32 Ci in 1997 compared with 34.74 Ci in 1996.

Of the 8 targets irradiated during the year one developed a minor leak in the weld that attaches the stainless steel foil to the target body. Natural rubidium and the produced radioisotopes are normally contained by the windows and target body. This was the second minor leak during irradiation of approximately 50 targets. The majority of the escaped activity was contained in the target cooling water and resin can. Both targets were processed for ^{82}Sr.

When work is necessary on the STF, the lower horizontal section is decoupled and removed from the vertical section containing water shielding. In the past, alignment of the mating flanges of these sections has been a problem when the lower section was reinstalled. During the spring shutdown an alignment jig was attached to the lower section to facilitate alignment of the sections.

Considerable dose was required to get the alignment jig to work because of limited clearances and hidden obstructions. The jig does not allow complete remote installation but it will significantly reduce dose in the future. This major improvement was made possible with the technical assistance of John Pederson and the design office. For the first time following three shutdowns, the STF was completely operational.

Other jobs in the spring shutdown included the replacement of the 2C extraction probe shear plate and the rebuilding of the Cs target beamstop on 2C5. A new shear plate made of molybdenum, that has better heat transfer, was installed on the extraction foil carousel. This allowed the extracted current to be raised from 50 to 80 μA. The cesium target beamstop was redesigned to remove the water voids in the beamstop cooling jacket. The cesium target was tested with the new beamstop during the summer but the current was restricted to 10 μA because of high temperatures in the collimator of the target protect monitor. Several energies were tried, without success, to reduce the beam spot in the collimator. It was assumed the beam width is caused by the 0.200 in. wide foil extracting several energies. To assist in tuning, the scanning wire monitor was moved from 2C4 to 2C5 during the extended fall maintenance. This diagnostic allowed tunes to be developed with a reduced beam width so that beam intensities of 22 μA were achieved. The cesium target temperatures and pressures responded as predicted as the current was increased. To achieve higher currents the protect monitor collimator will be modified to accept the wide beam.

Several shifts of cross section measurements of various radioisotopes were run at low beam intensities and tests were made for TRIM trailer recovery of ^{11}C generated in the STF cooling.

In late 1996, a major effort was put into encasing the depleted uranium shine blockers in stainless steel foil. This was necessary because the original nickel plating was flaking off. The cause of the flaking was unclear. These blockers are water-driven and continued in 1997 to operate erratically because of low water pressures in the vault. A redesign of the system is contemplated.

CONTROLS

CCS operation

The central control system (CCS) has performed reliably during 1997, contributing less than 16 hours of downtime. This number is considerably lower than the 10 year average of 24 hours. The majority of these 16 hours are due to critical hardware failures. In addition, there are numerous other hardware faults that are less severe and do not result in downtime. Power bumps and aging equipment combine to cause many of the hardware failures. The remainder of the downtime is typically due to software bugs and operating system problems, although these types of trouble generally result in inconvenience or confusion rather than beam downtime.

CCS upgrade

The removal of the NOVA computers was completed in December, 1996 and since then the VAX/Alpha computers and the new software have been performing all of the operational duties. As the year progressed, a number of software bugs and deficiencies were detected and addressed. This was anticipated as part of tying up loose ends in the upgrade project. The new hardware/software configuration allows problems to be much more easily identified but because of increased functionality, the solutions are often increasingly complex and sometimes slow to implement. Response time has also been affected by a significant quantity of new work on beam line 2A and a diversion of 30% of the group's software effort to ISAC control system support.

The decommissioning of the NOVAs and later their unracking and disposal allowed a reconfiguration of computer hardware and some CAMAC equipment. This was a significant reorganization that provided a number of improvements for reliabilty and maintenance.

BL2A

Hardware and software support for beam line 2A proceeded all year. A major milestone was reached when beam was extracted into beam line 2A during the spring shutdown. To accomplish this, monitoring and control of the extraction system, magnets, diagnostics, and numerous other devices was implemented. These control and display functions were developed to allow the new beam line to be run in the same manner as the other primary beam lines via the main console and the Xwindow based utilities. Preparations for the commissioning of the full beam line 2A in the spring of 1998 increased toward the end of 1997. As beam line 2A and ISAC facilities are commissioned, there will be a need for some changes in the main control room. One such change will involve adding more Xwindow terminals to accommodate dedicated displays of information associated with the new facilities.

I4/parity/proton therapy

Some support has continued for other projects such as the optically pumped ion source (I4), the parity experiment, and the proton therapy facility. One improvement in the I4 controls was the standardization of device control using normal device access software thus allowing easier software maintenance and more closely aligning this system with the CCS.

Miscellaneous

There have been numerous improvements as part of the process of tidying up after the upgrade project. In one area, the safety display pages were all reviewed and then standardized for layout and wording. The general display program, called XTpage, received several enhancements including support for hardcopy output in different formats, descriptions on the display page lists, and a new graph widget for colour plots. Changes also occurred in the CAMAC interrupt (LAM) handling. The Alpha computers can now handle LAMs and do so more quickly that the VAXes or the NOVAs before them.

The scan facility, which is a software package that monitors changes in accelerator devices and characteristics, has received considerable attention. This includes more scans, increased functionality, changes to the user interface, and internal optimizations.

Database applications continue to be important to CCS operation. The existing set-up has been expanded from Xwindow support to include Web applications. The Web set-up is a three-tier configuration consisting of the client using a Web browser on the platform of their choice connecting to a Windows NT server on a PC which runs the Web application server. The NT server is connected to an Oracle database running on an OpenVMS/Alpha system. This allows for good scalability at the Web server and a secure and reliable database engine. The database cpu has resided in the computer cluster used for development but this is expected to change to the production computer cluster in the new year to reflect the general opinion that the databases require a production level of access and reliability. Expanded requests this year have included the regular controls needs, conferences, ISAC, the library, and others.

OPERATIONAL SERVICES

Remote handling

ISAC

By year end more than 60% of the Remote Handling group effort was committed to the ISAC program, with Remote Handling personnel responsible for design coordination, parts procurement and assembly of ISAC target modules, and vacuum tanks, as well as design and supervision of the target hall shielding and services construction. Work is progressing at a slower rate on the hot cell design as a result of established priorities. We are waiting for commissioning of the target hall crane to begin design effort on the remote operation system.

Cyclotron servicing

The predominant remote handling job in the spring shutdown was the removal/replacement of the 2C extraction probe for work by Probes group. The fall minishutdown was markedly extended when a leak was discovered in a metal bellows on a lower cooling manifold in quadrant #2. This required removal of the centre region #1 resonator for access. This in turn required removal of the first-turn flag and wireways routed across the resonator panel. The bellows was replaced in the cyclotron tank using cryo-fit repair bushings, and the resonator, wireways and first-turn flag reinstalled. A major difficulty was encountered in this operation with vacuum sealing of the manifold C-seals. The “spare” seals in TRIUMF stock were found to have corroded during twenty years of storage. It was decided to replace the metal seals with conventional rubber O-rings. This location is close to the tank centre (low energy), far below the circulating beam centre line, and well shielded within the manifold block itself. Experience with rubber seals in the tank peripheral vacuum seal and other feed-throughs indicates that no additional problems should be encountered at this location.

Cyclotron elevating system

During the spring shutdown the upper bushings in stations #1 and #7 were dismantled, inspected and re-furbished. The upper seal wiper was replaced at station #1 during this operation. The elevating jack screws at station #11 were replaced with a pair of refurbished units. The jacks at station #10 were replaced with “spare” jacks and will be rebuilt before reinstallation. The “Highfield” gear reducer at station #1 was replaced with a spare unit. In October, trouble was experienced with the lid drive operation requiring mechanical re-alignment of all drive units and re-setting of the drive control.

Beam lines servicing

A recurring vacuum leak at the T2/M20-Q1 joint continued to plague us in 1997. One particular vacuum joint in this region had begun to experience premature and unexpected air leaks 5 times between 1992 and

1996. This year alone, new leaks were found and repaired in: the first week of January, the end of February, the beginning of May and the end of August, four separate times in all. During each repair, attempts were made to discern the cause of the premature failure. This inquiry was made difficult by the high residual fields in this area. Remote measurements, visual inspections and joint seal impressions were made in all instances. There is a significant alignment discrepancy between the flange centre lines of the T2 beam tube exit flange, and the M20-Q1 beam tube entry flange. This misalignment occurs in both angular and transverse coordinates. There is no known or conjectured cause for the misalignment. Beginning with the January repair, attempts were made to correct for the alignment discrepancy using a tapered indium carrier ring in place of the conventional parallel section ring. During early repairs a cautious approach was taken in the degree of correction attempted, hoping to solve the problem with minimum downtime, and having a limited understanding of the magnitude of the problem. Above all, we were concerned about the consequences of major modification to the operational system. By the fourth leak occurrence it was evident that more drastic measures had to be taken, both in evaluation of the problem and extent of solution undertaken. This repair took a full month. The degree of angular misalignment was examined, the lateral offset measured, and the relationship of the flanges and joint mechanism evaluated. Given these data, a three-dimensional layout of the flange relationships was developed to determine the resultant effects of any modification. It was discovered that earlier attempts to correct the problem had resulted in an imbalanced mechanical loading of the joint. By changing the taper of the carrier ring, rotating the "thick" section and correcting load imbalance with one thinner drive pin, we were better able to correct the diverse misalignment conditions. The recorded total personnel exposure for the final repair was 7.51 mSv, very respectable given the residual radiation fields of 95 R/hr at the flange.

During the year, remote handling assistance was also provided for repair of a drive feed through on the M15 slits, replacing a ceramic insulator on 1AQ10, rewiring the limit switches on 1AVA8 gate valve, and replacing the 1AM9 monitor. Modification was made to the M13 gate valve roller assembly, and reworking of the 1AW2 window water cooling at TNF. ISAC support included replacement of the 2A exit horn flange, and installing of new vacuum flanges on 2ACM1/2AVVR1.

Hot cells/targets

This year the T1 Mark-1 ladder drive coupling was replaced, the 10 mm graphite target replaced twice, the protect monitor realigned, and the C-seals replaced. The 10 mm graphite target was also replaced twice on the T1/Mk-2 target, and a 12 mm Be cassette replaced. The T2/Mk-1 ladder drive coupling and motor were replaced, as were the ladder C-seals. A 10 cm Be target cassette was replaced on the T2/Mk-2 target and the lower C-seals replaced. The T2 protect monitor was changed this year due to heat damage from the prototype T2 10 cm graphite targets. The M8 beam blocker required replacement of the upper O-ring. The M20 beam blocker required rebuilding of the air actuator cylinders with replacement of the actuator rod O-rings and the supply valve mounted on the cooling package. The T2 cooling package was upgraded, the hydrogen recombiner removed and a new expansion tank located on the upper mezzanine. The pump, filters and sealing O-rings required replacement this year due to overheating when the supply solenoid valve inadvertently closed. The T1 cooling package had the filters, pump and pump contactor replaced to prevent a similar incident. Resin exchange cans were routinely replaced on both cooling packages. Hot cell work included; replacement of O-rings in the M20/Q1 flexible cooling line jumper, and modification of the 2C solid target and intermediate vertical pipe section. The exchange resin in the 2C resin cans was replaced twice.

Magnet and power supplies

Most of the group's effort was directed at routine maintenance of the magnet power supply system. As in previous years a major activity was the replacement of leaking transistor pass bank cooling plates. Support was provided to the ISAC project through installation of power supplies for the vault section of beam line 2A. Supplies were procured for 2A magnets, which are to be commissioned during the spring, 1998 shutdown.

Tests were carried out to establish noise suppression for purposes of the current readbacks on the CTS power supplies, with the resultant circuitry anticipated to be installed in M13 supplies. The purpose of this work is to allow the Mux signals to be more effectively used as a tuning tool for experiments.

As in previous years, budget restraints precluded the replacement of aging equipment which at some point will have to be faced. A proposal was made for possible new acquisitions for the next 5-year plan.

Electrical systems

Electrical Department

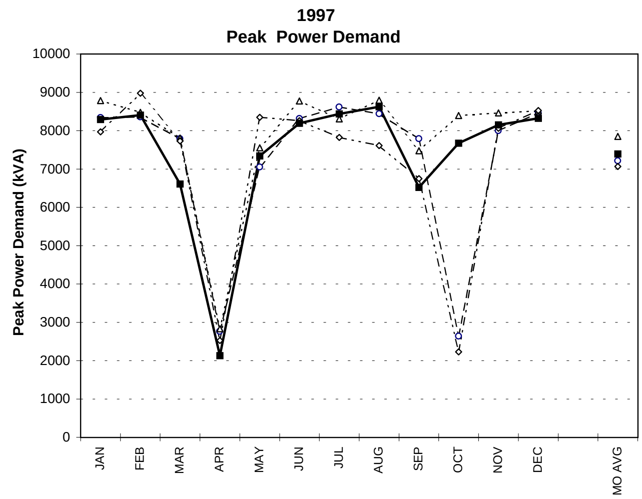
The Electrical Department handles all aspects of the electrical infrastructure on site, including cyclotron operations, experimental facilities, power delivery and site services. Activities span from design to engineering, installation, operations and maintenance with the objective of ensuring the delivery of power to the users in a safe, reliable and economical way. The facility power distribution has increased significantly over the years. With ISAC coming into operation we have reached about 10 MVA of load requirements. Contacts were made with the power utility and the UBC Plant Operations for support and coordination of emergency situations associated with loss of power to the site. Engineering support to TRIUMF users is also a responsibility. The department was also heavily involved with the ISAC project and the CERN collaboration, as reported elsewhere.

Routine maintenance included lighting, power distribution centres, motors and transformers. A water leak from the roof of the accelerator building caused the failure of one of two power transformers in the proton hall. A bridge connection was installed from the other distribution centre to minimize the disruption to the parity experiment during the repair. The transformer was re-installed and energized early in May. Two major lightning storms hit the South Campus during the summer and caused extensive damage to electronic components. The fire alarm system was one of the systems most affected. Many detectors and control boards had to be replaced, especially in the Chemistry Annex/Nordion loop. The installation of the upgrade of the fire alarm system to the accelerator building and services annexes stretched into the second half of the year and required more time than anticipated. To minimize the areas without fire alarm coverage only one floor at a time could be taken out of service during the change-over to the new system. It is anticipated that the system will be fully operational by February, 1998.

Power delivery

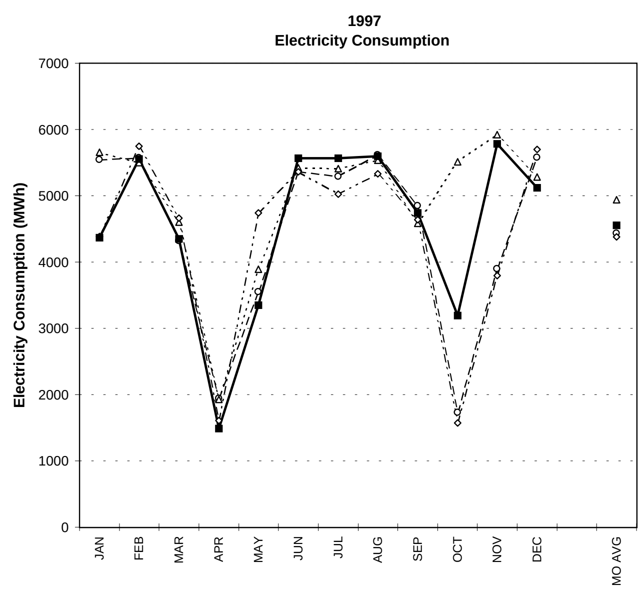
BC Hydro presented a detailed report to the GVRD and Pacific Spirit Park Management about the tree hazard to the overhead transmission line in the park. The survey was commissioned following the aftermath of last winter's snow storm. The Parks Board met in the fall in preparation for public hearings early in 1998. In parallel to these actions the UBC utility division, BC Hydro, and TRIUMF met to study ways to ensure enough power capacity to the South Campus to continue operation even in case of loss of the overhead line. Duplication of the line being out of the question, a power bridge between the two 60 kV transmission lines, 60L56 to UBC and 60L57 to the South Campus, appears to be the next feasible solution of choice. This would allow power to TRIUMF from 60L56 in case of loss of the Hydro portion of 60L57. BC Hydro indicated that they were prepared to finance the project. If funding is finalized in time it may be implemented during the cyclotron winter shutdown.

The energy management goal was tightened in the effort to keep expenses within a reduced budget while starting up systems of the ISAC facility. Load shedding opportunities were pursued more aggressively and the help of the cyclotron operators should be acknowledged. The monthly kVA power demand, averaged over the calendar year, increased 4.6% from 7067 to 7391 (Fig. 100); this was expected as more ISAC systems are started. The annual electricity consumption increased from 52.56 GWh to 54.67 GWh. The average monthly consumption was 4556 MWh, up 4.0% from the previous calendar year (Fig. 101).



YEAR	MONTH AVERAGE	UNITS
1994	7212	kVA
1995	7848	kVA
1996	7067	kVA
1997	7391	kVA

Fig. 100. Electrical system power demand — four year comparison.



YEAR	TOTAL	MONTH AVERAGE	UNITS
1994	53.2	4.437	GWh
1995	59.2	4.938	GWh
1996	52.6	4.381	GWh
1997	54.7	4.556	GWh

Fig. 101. Electrical system energy consumption — four year comparison.

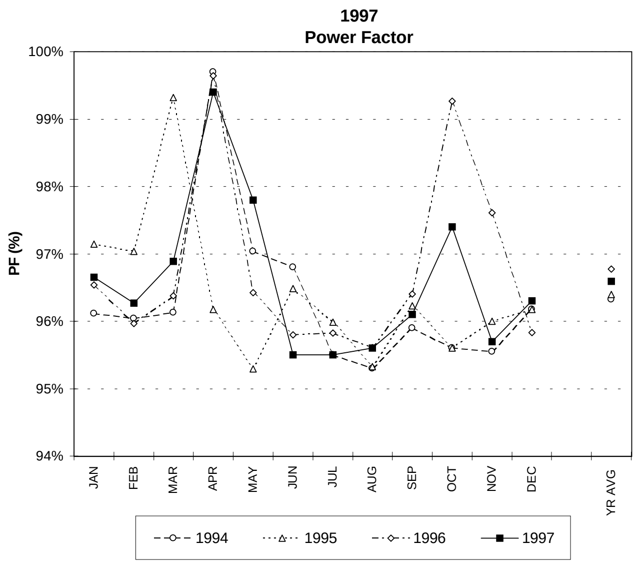


Fig. 102. Electrical system power factor — four year comparison.

The power factor edged down 0.2% to 96.6% (Fig. 102). The load factor, the index that measures how well the power demand is used by the facility, remained unchanged at 87%.

Mechanical systems

The largest single effort went into the ISAC project. At the end of the year all major systems were designed, most were installed; but commissioning and official start-up are yet to come. Systems initially running were the non-active LCW and compressed air which were connected to the off-line ion source (OLIS), building heat, site drainage, cooling tower, fire sprinklers, and domestic hot and cold water. Not started yet were the active and non-active exhaust systems, air conditioning, and low active LCW. The 35 ton main crane was signed over as accepted by TRIUMF and was taken over for use. Connection to cooling water systems was started for the 2A vault and tunnel magnets. The high active LCW system design was completed.

The second most visible project was the HVAC system for the HERMES clean room. A rather unusual engineering problem was solved with a system which successfully regulates the room temperature to ±1°C with less than 50% relative humidity.

Other mechanical engineering service users included: RFQ electrode heating, RFQ cooling tube water flow and control orifices, DTL stem heating calculations, lifting beam designs for the RFQ lid and the ISAC transformer, and flow calculations for the TISOL cryo pump lines. Continuing assistance was given to Nordion for the cooling tower replacement and room 221 air conditioning. A large effort went into the concept design and budgeting for the proposed radiochemistry lab for the MESA building.

Major repairs and upgrades included: a new remote control for the vault crane, overhauls of the CuLCW pumps, new sheaves and bearings for the cooling tower fans, a new HVAC air handling unit for the CRM lab, installation of a new building air compressor, overhaul of the SE 25 ton main hall crane hoist gearbox, and replacement of ME 141 compressor shaft seal. A no-flow alarm was installed into the exhaust duct of the decontamination room fume hood. The TISOL vacuum pump exhaust was connected to the monitored and flow measured TISOL active exhaust duct. LCW cooling water service was run into a new rf area in the proton hall extension.